

excess. In the regions where the precipitation is about equal there is little damage from wind. Late summer rains generally come as daytime showers, while early summer rains fall more gently and at night. Thus, while the total seasonal precipitation may be equal in two given regions, the economic effects of the difference in amount between early and late summer [or winter and summer] may be considerable. "A warm rain presumably has a greater leaching effect than cold rain or snow, and regions subject to heavy summer rains, like most of Florida, generally have poorer soils and more swamps than where the summers are dry, as in California." Soil appears to be most fertile where the excess comes in early summer, as is evidenced by the fertility of the Mississippi Valley as contrasted with the less fertile soil of Florida.

"The same precipitation factor seems to control indirectly several economic features. For example, most of the developed water powers in the United States are within two or three hundred miles of the line of equilib-

rium between early and late summer rains, though this may be chiefly because the same topographic factors that make the water power possible also influence the seasonal rainfall in some way. Some correlations between seasonal rainfall and crops are easily made. Alfalfa, wheat, figs, and upland cotton are not raised much where the late summer rainfall exceeds that of early summer by more than three inches, while sugar cane, pineapples, grapefruit, and sea-island cotton thrive where late summer rains prevail. But, of course, the soil [and temperature] have a great deal to do with this, too."

The further correlation of this precipitation distribution with soil, vegetation, etc., in the other parts of the world on such a basis as this would be of interest. Thus, this line of investigation opens a new and a large field, and it is possible "that by shifting, a little, the periods compared, more significant results can be obtained."—*C. L. M.*

NORMAL PRECIPITATION IN UTAH.

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(Dated; Weather Bureau, Salt Lake City, Utah, Sept. 13, 1919.)

SYNOPSIS.—The precipitation in Utah as shown by about 180 records of 5 to 49 years' length is least in the depressions and greatest on the higher windward slopes of the mountains generally, the amount being about 10 times greater on the higher mountains than on the depressions to windward. The increase with altitude is about 4 inches per thousand feet on the windward or western slopes and about 5.50 inches per thousand feet on the opposite side of the mountain ranges which intercept storm tracks. A slight decrease is shown near the crests, and the increase begins some distance to windward of the mountains. An important nonconformity appears on slopes which are interrupted by important initial barriers, beyond which there is sometimes a decrease and always a change in the rate of increase. The windward sides of intermediate valleys are drier usually than the leeward sides.

Secular variations in annual and monthly amounts are shown to be without uniformity or reliability. Decade means for every consecutive 10 years in several groups of stations show variations amounting to from 15 per cent to 19 per cent of the 26-year means. The stability of 26-year and longer means is shown to be within 3 per cent the addition of any 10 years' record changing the mean no more than this amount. Certain supposedly wet or dry cycles are shown to be of opposite value or absent from a number of months and stations, and the January to May precipitation is shown to be comparatively stable and subject to less fluctuation. Types of monthly distribution are presented.

INTRODUCTION.

The accompanying chart of average annual precipitation in Utah (chart J.C.A. I) has been prepared from all authentic data available at the close of the year 1918, the records having been adjusted as nearly as possible to the 26-year period, 1893–1918, and the interpolation having been made with every practicable consideration for topographic influences.¹

The records used have been made principally in the settled communities where cooperative observers were available, at an average altitude of about 5,250 feet above sea level, a figure that has not varied materially through any period of years. The number of stations reporting regularly has been about as follows: 1890, 12; 1895, 25; 1900, 45; 1905, 60; 1910, 75; 1915, 110, and 1918, 125. About 180 localities are represented in all, or nearly one-half the number of post offices in the State. The general average annual precipitation is about one-third as much as in Illinois, the dearth being due to distance from the Pacific Ocean, which is the principal moisture source, and to the interception of the moisture-bearing winds by the coast ranges and Sierra-Cascades. The

Wasatch Mountain range forms the principal topographic control of precipitation within the State as it intercepts most of the storm tracks at about right angles; its westerly slopes therefore, as well as the northerly slopes of the Uinta Mountains, receive the State's heaviest precipitation. A comparatively heavy precipitation is also wrested from passing storms by the La Sal and Elk Mountains and their surrounding plateau lands in southeastern Utah.

Contrariwise, the depressions over western Utah which formed the bottom of the prehistoric Lake Bonneville (the Great Salt Lake Desert) is the State's most arid region. The slightly higher plains regions of western Utah generally, from which rise numerous ranges of hills and minor mountains, and the broad basins of the Green and the Colorado Rivers in eastern Utah, are also relatively arid, as a rule.

INCREASE WITH ALTITUDE.

The transition from arid to moist conditions is noticeably more gradual on the windward slopes of the major topographical barriers than on the leeward slopes; the 10-to-15-inch zone (chart J.C.A. I) for instance, being much narrower along the east slope than along the west slope of the Wasatch Mountains. This condition is also rather well-defined in the minor intermediate valleys the western portions of which are usually drier than the eastern portions. These valleys as a whole are successively drier to leeward (eastward) than similar valleys located in the more westerly parts of the broad mountain range in general.

The precipitation increase with altitude begins at a considerable distance to windward of the mountain base, and is progressive at a fairly regular rate on the long gradual uninterrupted slopes, until near the summit where it decreases slightly. The geographical area of diminished precipitation, however, is naturally limited and of reduced consequence. The precipitation on the western slope of the Wasatch Mountains at from 7,500 to 8,750 feet altitude is about ten times the amount over the salt deserts 60 to 75 miles to windward.

Compilations of data depicting the increase of precipitation with altitude on the western slope of the Wasatch Mountains for practically all groups of adjacent stations

¹ The author acknowledges the valuable assistance of Mr. C. F. Korstian, forest examiner, in charge of Research, District No. 4, U. S. Forest Service, Ogden, Utah.

with simultaneous records have been made, many of which are shown in Table 1. Generally the altitude-increase relation is found to be rather irregular, varying with the local topography, though on gradual slopes without important interruptions in topography, the increase is strikingly uniform.

An average or composite graph is presented herewith (fig. 1) which represents an assumed slope (having its nearest counterpart in Salt Lake County from Saltair to Silver Lake) rising from a station situated 10 miles west of the base of the mountain at an altitude of 4,250

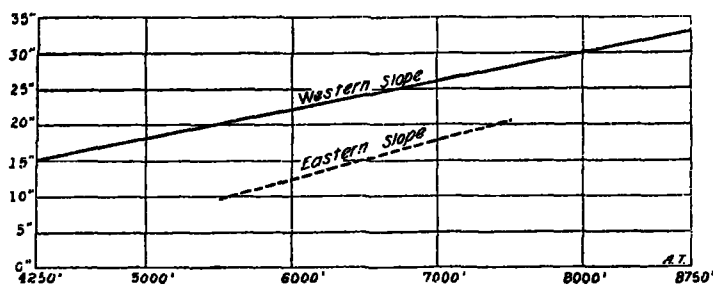


FIG. 1.—Precipitation increase with altitude.

feet, to a station 30 miles to leeward at an altitude of 8,750 feet, within 5 miles distance and 1,250 feet altitude of the general crest line.

From the original graphs and some of the tables herewith it is evident that the decrease in precipitation near the crest occurs within the last 1,250 feet as a rule, though there is not sufficient data at hand to establish either

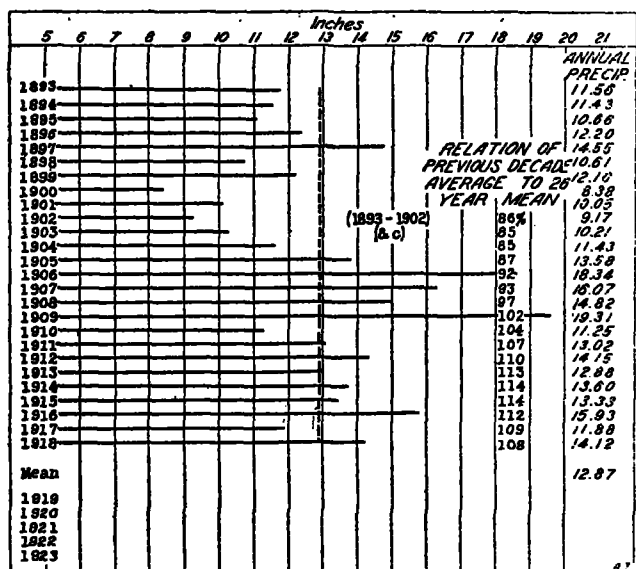


FIG. 2.—Average precipitation in Utah and variation of decade means, in percentage of the 20-year mean.

this recurve on the graph or the initial curve at the base in true proportions. In all groups of adjacent stations where the higher stations are situated to the lee of the initial ridge or barrier of the mountain range an important nonconformity appears in the graphs. (Table 1, I and J.)

The composite altitude-increase graph herewith (fig. 1), shows an increase of precipitation of from 15 inches annually at the lower station to 33 inches at the higher station, or uniformly 4 inches per year for each thousand feet.

Attempts to determine the elements of the counterpart of this graph on the leeward slope of the mountains have been partially defeated through the lack of stations and data, though it is very nearly 5.50 inches per thousand feet on an assumed or composite slope (having its nearest counterpart in Wasatch and Duchesne Counties from Duchesne to East Portal stations) running from a base station at 5,500 feet elevation with 9.50 inches annual precipitation to a station within 1,000 feet of the crest at 7,500 feet altitude with about 20.5 inches precipitation, the stations being about 36 miles apart. The values on this eastern-slope graph are about 55 per cent of the values on the western-slope graph, being about 45 per cent at 5,500 feet altitude and 65 per cent at 7,500 feet altitude.

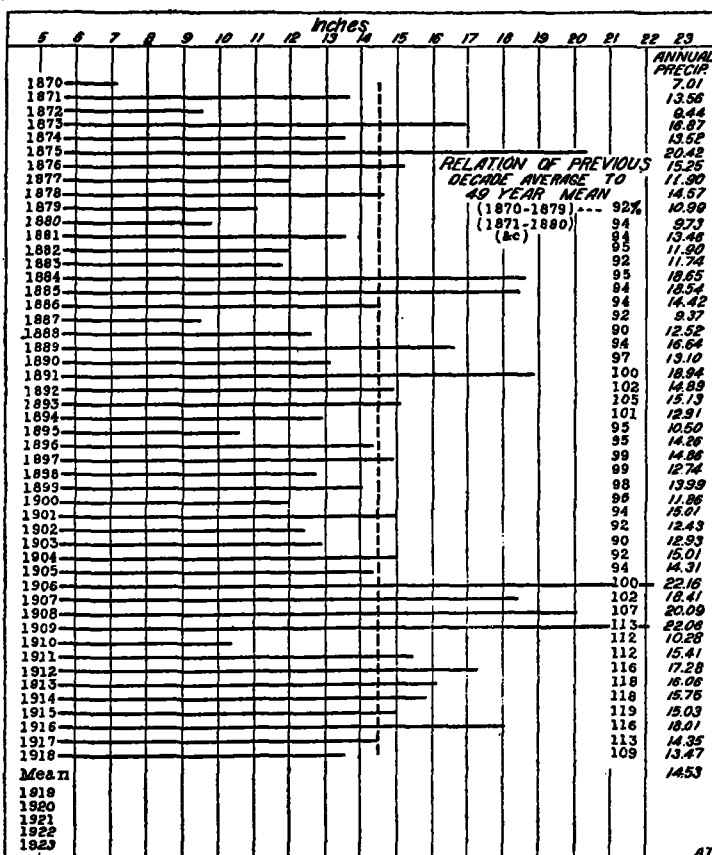


FIG. 3.—Average annual precipitation at Corinne, Ogden, and Salt Lake City combined, showing fluctuation of annual amounts, and variation of the decade means.

The precipitation decreases rapidly immediately to the lee of the summit as compared with amounts to the west of the crest (Table 1, G and H) as shown at the two portals of Strawberry tunnel (United States Reclamation Service) 4 miles apart, between which the Wasatch crest rises about 900 feet above the tunnel; and at Scofield which is about 7 miles to the lee of the summit and about 1,500 feet lower.

An anomaly seems manifested in the diminishing amount with increase in altitude in southeastern Utah County (Table 1, J) but while there is some doubt as to part of the early records at Thistle and Soldier Summit it will be noted that the initial topographic barrier is an important one and is between Provo and Thistle, the large influence of which is apparent in the shorter records at Maplewood and Spanish Fork (near). The effect of the initial barrier is also manifested in Weber, Morgan

and Summit Counties (Table 1, I). In Table 1, K and L, the initial altitude barrier is in a sense between Provo and Heber, though the main crest of the range is considerably to the east of Heber. The slight decrease at Heber shown in Table 1, L, may be attributable to the nonconformity of a periodic variation.

SECULAR VARIATIONS AND ANNUAL FLUCTUATIONS.

Periodic variations in annual amounts of precipitation appear somewhat irregularly in practically all records of 20 years or more the oscillations being of varying length and value (figs. 2, 3, 4, and 5); and there are variations in crop successes, stream flow and other phenomena to corroborate these cycles; but variations in high-water stages in streams and in the number and volume of seeps and springs, often contradictory, are more frequently the result of grazing, water diversion, or other unnatural conditions and should not erroneously be attributed to precipitation changes.

These cycles, which vary in length and intensity for different localities, are not indications of a permanent

The variability of the precipitation in the major agricultural districts of western Utah where long weather records are available is shown in the 8-station group herewith (fig. 4). The 10-year means have fluctuated from 89 per cent to 111 per cent of the 26-year mean. The wettest single year is about 144 per cent and the driest about 71 per cent of the 26-year mean. The addition of a single year as wet as the wettest or as dry as the driest changes this mean less than one-half of 1 per cent; and the addition of 10 years as wet as the wettest decade and as dry as the driest decade changes the mean only about 3 per cent at these stations combined. This 26-year mean is about 105 per cent of a calculated mean for 49 years ending with 1918, as determined by adjustment with the 3-station group (fig. 3).

The uncertainty and irregularity of the periodicity is apparent from an examination of Table 2, wherein the periodicity at Provo and Logan shows a much wider range than at Salt Lake City and Fillmore; and at Levan the periodicity practically disappears. An equally important fact is that the periodicity does not appear

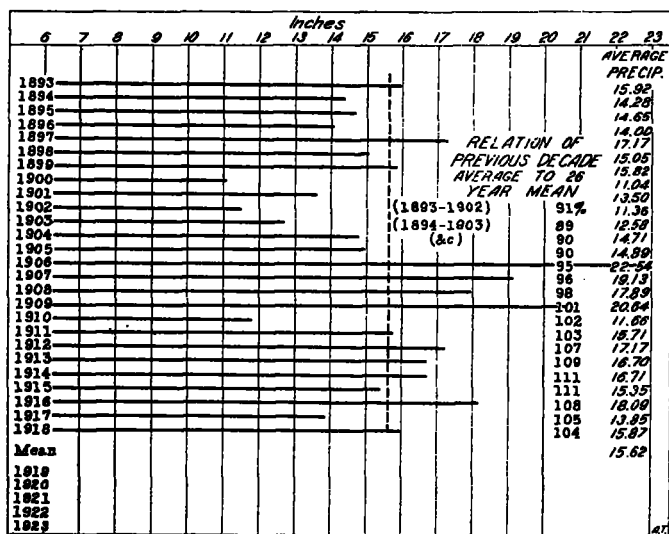


FIG. 4.—Average annual precipitation at Logan, Ogden, Salt Lake City, Heber, Provo, Levan, Fillmore, and Parowan, Utah, combined, showing fluctuation of annual amounts, and variation of the decade means.

climatic change and do not form a trustworthy basis for forecasting. And in adjusting short records to long-term averages at adjacent stations the general topography must be similar, the stations be situated within comparatively short distances, and the period compared be as long as possible. Records of even 10 consecutive years' length may be discrepant from the true normal by 15 per cent or even 20 per cent in extreme cases. (figs. 2, 3, and 4, decade percentages.)

The longest records available in Utah are at Corinne, Ogden and Salt Lake City (fig. 3) in which the fluctuation of the 10-year mean about the 49-year mean is from 90 per cent to 119 per cent, thus emphasizing the necessity for a long term of observations for establishing a true normal. The amounts in the wettest single years in this group are about 147 per cent and the driest year about 47 per cent of the 49-year average. However, the addition of a single year as wet as the wettest or as dry as the driest, changes the mean only 1 per cent; and the addition of 10 years as wet as the wettest decade changes the mean only 3 per cent and the addition of 10 years as dry as the driest decade changes the mean only 1.7 per cent.

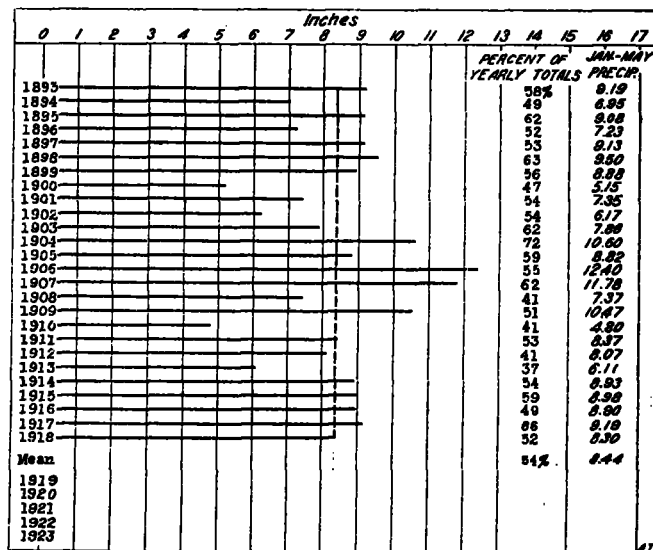


FIG. 5.—Seasonal precipitation, January to May, inclusive, at Logan, Ogden, Salt Lake City, Heber, Provo, Levan, Fillmore, and Parowan, combined, and percentage of yearly totals.

uniformly in all the months of the year (Table 3). March and May, whose precipitation is highly important to water users and to nonirrigated vegetation generally shows swings of the precipitation cycle that are opposite in value to those appearing in all other months; and there is practically no variation in the values for November during the supposed wet and dry cycles. Thus, in spite of the invitation in the records themselves in many cases to give credence to these cycles it is safest in general to disregard them.

A rather large share of the value represented in the monthly means of precipitation is often due to a few isolated downpours of rain of little agricultural or storage importance. Therefore the tendency shown in Table 3, items 4 and 5 (unnumbered) is for the dry months to exceed the wet months in number. This condition is also shown in the records for the State as a whole. The fact is further apparent in the next two items of that table of the relation of the wettest and driest months to the mean values. February, March, April, and December appear to be rather stable in this particular.

It will be noted that 54 per cent of the precipitation comes in the western Utah group from January to May, inclusive (Table 3), this being the season when there is a considerable dependence on the precipitation by agricultural and power interests, owing to the necessity for supplying storage reservoirs and providing snow stores in the mountains for summer stream flow. It also appears (Table 3 and fig. 5) that the precipitation in this season is subject to somewhat less fluctuation than that during other portions of the year and for the year as a whole. The average precipitation for these five months from 1893 to 1905, inclusive (the alleged dry cycle), is 96 per cent and for 1906 to 1918 (the alleged wet cycle) is 104 per cent of the 26-year average, as compared with 91 per cent and 109 per cent for the years as a whole in the same eras.

There are two fairly distinct types of precipitation distribution in the State (Table 3, last three items), the maximum amount in western Utah coming from about January to May, inclusive, and in eastern Utah from July to October, inclusive, though these types are not manifested uniformly in all stations within the areas mentioned.

TABLE 1.—Precipitation increase with altitude, in Utah.

(See text.)

	Stations.	Period of record, inclusive dates.	Elevation above sea level.	Average annual precipitation.
A	Kelton, Lemay, and Wendover....	1914 to 1918.....	2,429	5.21
	Corinne and Saltair Beach.....	do.....	2,420	14.20
	Brigham City, Ogden, Riverdale, Farmington, Salt Lake City, University of Utah, and Midvale.	do.....	2,433	16.59
	High Line (City Creek), Lower Mill Creek, Alpine, and Lower American Fork.	do.....	2,554	18.82
B	Salt Lake City.....	1915 to 1918 ¹	4,400	2.98
	University of Utah.....	do.....	4,500	3.48
	Lower Mill Creek.....	do.....	4,959	4.18
	Cottonwood Nursery.....	do.....	7,400	6.28
	Silver Lake.....	do.....	8,700	6.24
C	Salt Lake City.....	1916 to 1918.....	4,400	15.30
	University of Utah.....	do.....	4,500	15.82
	Lower Mill Creek.....	do.....	4,959	22.45
	Silver Lake.....	do.....	8,700	40.65
D	Manti.....	37 months, mostly June to November, 1914-1918.	5,575	40.01
	Great Basin Experiment Station.....	do.....	8,750	83.80
	Alpine substation.....	do.....	10,000	70.71
E	Spanish Fork.....	1911 to 1913.....	4,711	18.21
	Maplewood.....	do.....	4,800	19.91
	West Portal ⁴	do.....	7,650	28.40
F	Provo.....	1909 to 1913.....	4,532	17.39
	West Portal ⁴	do.....	7,650	28.33
G	West Portal ⁴	January, 1912, to September, 1913.	7,650	50.15
	East Portal ⁴	do.....	7,606	39.20
H	East Portal ⁴	1912 to 1916.....	7,606	22.54
	Scotfield.....	do.....	7,625	18.15
I	Ogden.....	1905 to 1916.....	4,310	19.77
	Heber.....	do.....	5,301	21.26
	Castle Rock.....	do.....	8,240	17.00
J	Provo.....	11 years ²	4,532	14.99
	Thistle.....	do.....	5,033	13.36
	Soldier Summit.....	do.....	7,454	11.68
K	Provo.....	26 years ³	4,532	15.31
	Heber.....	do.....	5,593	17.27
L	Provo.....	7 years ³	4,532	17.70
	Heber.....	do.....	5,593	17.12
	East Portal ⁴	do.....	7,606	21.06

¹ June to September, inclusive.² Average elevation.³ June to September average.⁴ Strawberry Tunnel.⁵ Total for period indicated in column 2.⁶ Identical years.

TABLE 2.—Table showing differences between rainfall of two 13-year periods.

Stations.	1893-1905		1906-1918		26-year mean, 1893-1918.
	Mean.	Per cent of 26-year mean.	Mean.	Per cent of 26-year mean.	
	Inches.		Inches.		Inches.
Logan.....	14.20	86	18.89	114	16.54
Ogden.....	14.00	87	18.25	113	16.12
Salt Lake City.....	15.20	95	16.95	105	16.08
Heber.....	16.25	94	18.25	106	17.27
Provo.....	12.67	83	17.95	117	15.31
Levan.....	15.75	98	16.24	102	16.00
Fillmore.....	13.61	95	15.18	105	14.40
Parowan.....	11.85	90	14.40	109	13.13
8-station mean.....	14.20	91	17.02	109	15.82

TABLE 3.—Precipitation periodicity and variability at Logan, Ogden, Salt Lake City, Heber, Provo, Levan, Fillmore, and Parowan, combined, representing the agricultural district of western Utah.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
26-year mean.....	1.64	1.60	1.94	1.50	1.76	0.69	0.76	0.87	1.14	1.31	1.15	1.22	15.62
1893-1905 mean.....	1.28	1.54	2.01	1.49	1.82	.47	.56	.78	.94	1.07	1.16	1.09	14.21
1906-1918 mean.....	2.00	1.66	1.87	1.51	1.70	.92	.96	.95	1.34	1.55	1.21	1.35	17.03
Number of times greater than 26-year mean.....	9	12	10	11	12	10	10	11	12	13	12	14	13
Number of times less than 26-year mean.....	17	14	16	15	14	16	16	15	14	13	14	12	13
Wettest month in per cent of 26-year mean.....	210	190	190	192	285	319	246	306	227	266	192	184	144
Driest month in per cent of 26-year mean.....	38	29	12	24	31	6	24	10	3	5	0	12	71
Monthly distribution in percentages.....	10.5	10.0	12.5	10.0	11.0	4.5	5.0	5.5	7.0	8.5	7.5	8.0	100
Monthly distribution in eastern Utah, per cent.....	9.0	7.5	8.5	6.5	7.0	4.5	11.0	11.5	12.5	9.5	5.0	7.5	100
Precipitation in Utah:													
26-year mean.....	1.37	1.28	1.47	1.09	1.23	.58	.87	.92	1.03	1.10	.96	.98	12.87
Distribution in percentages.....	10.5	10.0	11.5	8.5	9.5	4.5	7.0	7.0	8.0	8.5	7.5	7.5	100